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Electrical Instruments for Use With Explosives Systems

Recommended for approval by the ES&H Working Group

Approved by: Robert W. Kuckuck
Deputy Director for Operations

New document or new requirements

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17.4

Electrical Instruments for Use With Explosives Systems*

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Electrical Instruments for Use With Explosives Systems

1.0 Introduction

Electrical instruments are frequently used at LLNL to analyze and verify the continuity of electrical circuits associated with explosives systems. LLNL has developed a program to review, certify, and control these instruments so that, when they are used properly, they cannot cause damage to or initiate a reaction in explosives systems. Personnel using any electrical instrument on explosives systems shall consider the effect the instrument's output may have on that system and determine if additional controls (e.g., remote operation) may be necessary.

This document describes the instrument review, type categorization, and certification process as well as control requirements for electrical instrument use on explosives systems. A list of terms and definitions is provided in Appendix A, and a list of approved instruments is in Appendix B.

This document governs the use of electrical instruments at the Livermore site and Site 300, and LLNL operations at the Nevada Test Site (NTS). This program is based on the requirements of the *DOE Explosives Safety Manual*, DOE M 440.1-1. The NTS must also comply with DOE O 452.2B, "Safety of Nuclear Explosives Operations."

2.0 Hazards

The major hazard from explosives is personal injury or property damage caused by heat, blast, noise, fumes, and flying debris or projectiles from unintentional or inadequately controlled ignition or explosion of such materials. Injuries ranging from minor to fatal could include trauma, lacerations, eye injury, hearing impairment, and burns. Property damage could range from minor to major. Electrical test meters used for checking continuity and resistance of electroexplosive devices could supply an excessive amount of current through either normal operation or fault condition. Many explosive-initiating devices may be fired by low levels of energy; i.e., 0.1 Joule or less.

3.0 Controls

3.1 Explosives Systems

LLNL has established categories of instruments so that each instrument type can be applied to one or more of the following explosives systems. See Section 3.2 for a description of the instrument types.

3.1.1 Initiating Systems

High-power-initiating systems. Electrical circuits that

- Are directly connected to an exploding bridgewire (EBW) detonator, exploding foil (slapper) detonator, or a similar high-power electroexplosive device (EED).
- Are designed to initiate the explosive.
- Require high-energy levels (typically requiring peak power levels of 10^5–10^6 watts) to initiate the attached EED.

Low-energy or hot-wire-initiating systems. Electrical circuits that

- Are directly connected to any non-EBW, nonslapper EED, or other nonhigh-power EED (e.g., a hot-wire actuator, blasting cap, squib, ignitor, or similar EED).
- Are designed to initiate the explosive.
- Can initiate the attached EED at any peak power levels (frequently as low as only a few watts or energy levels of 0.1 joules or less).

Note: Any initiation system that does not meet the requirements of a high-power initiating system is classified as a low-energy initiating system.

3.1.2 Noninitiating Systems

Noninitiating systems include electrical circuits that are attached or adjacent to any explosive material but are not designed to initiate the explosive. These circuits are connected to sensitive control systems, mechanical systems, or auxiliary circuits used with explosives or device components (e.g., circuits connected to arming and firing system component circuits, strain gauges, pin switches, pressure transducers, thermocouples, or equivalent systems).

3.2 Instrument Classification and Identification

Instruments are classified into three categories based on the electrical characteristics that affect the safe use on explosives systems. The established instrument categories are designated as Type I, Type II, and Type III. Color-coded labels are assigned to each instrument type for ease of recognition. For LLNL explosives operations, these labels shall only be applied to instruments that have been approved by the High Explosives Instrument Committee (HEIC) and shall have the corresponding electrical characteristics.

All electrical instruments classified as Type I, II, or III shall be specifically approved and meet the design criteria in Section 3.3. Any electrical device that does not meet these criteria may be used on explosives systems only if (1) management approves the activity as a remote operation, and (2) adequate personnel shielding or sufficient separation distance is provided. The control, maintenance requirements, and calibration requirements (if applicable) for nonapproved instruments shall be specified in an approved safety plan (Operational Safety Plan [OSP] or Facility Safety Plan [FSP]) and authorized by an approved Integration Work Sheet (IWS). The safety plan shall be available in the area where the instrument is used.

3.2.1 Type I Instruments

Type I instruments are those designed for use on low-energy or hot-wire initiating systems. The maximum design short-circuit current for Type I instruments is less than 10 mA; the label for these instruments is color-coded green with silver letters (see Fig. 1).

Figure 1. Label for Type I instruments.

3.2.2 Type II Instruments

Type II instruments are those designed for use on high-power initiating systems. The maximum design short-circuit current for Type II instruments is less than 100 mA; the label for these instruments is color-coded green with red stripes (see Fig. 2).

Figure 2. Label for Type II instruments.

3.2.3 Type III Instruments

Type III instruments are restricted for use on noninitiating systems only. These instruments shall meet the electrical requirements for the explosive work area where used and shall be approved by the HEIC for the specific application intended. The maximum design short-circuit current for Type III instruments may exceed that of Type II; the label for these instruments is color-coded red with silver letters (see Fig. 3). An approved IWS is required for all Type III instrument applications.

Figure 3. Label for Type III instruments.

3.3 Instrument Design Criteria

To gain approval as a Type I, II, or III instrument for use on explosives systems, all instruments shall (1) meet the general design criteria below; (2) be current-limited; and (3) have their wiring diagrams and internal circuitry design analyzed, examined, and certified before approval (see Section 3.4). The criteria is as follows:

- The cases for Types I, II, and III instruments shall be dust-resistant. Fixed instruments located in control rooms are exempt from this requirement.
- The current-limiting features of an instrument shall be internal to the test instrument and shall not be dependent upon a fuse or the test circuit-load characteristics.
- Batteries supplying power to any instrument shall be of minimal voltage; they shall not be higher voltage than the amount necessary to perform the tests.
- An instrument shall not have, within itself, enough energy or combustible material to produce a fire if that instrument malfunctions. Self-extinguishing or noncombustible materials must be used wherever possible.
- The output current, through a resistance equivalent to that of the minimum resistance initiator of the explosives system class, should not exceed 1% and shall not exceed 10% of the no-fire rating for the most sensitive initiator of the class. For example, Type I instruments are limited to less than a short-circuit current output of 10 mA; Type II instruments are limited to less than 100 mA. The calibration of currents will be verified with calibrated test instruments traceable to the National Institute of Standards and Technology (NIST) and certified by DOE contractor personnel in accordance with standards established by a DOE-contractor-controlled calibration laboratory. *This requirement shall not be delegated to a non-DOE-contractor-controlled calibration laboratory*.
- Instruments shall be designed such that a single component failure will not allow available current from the terminals to exceed the maximum design limit of the short-circuit current for the instrument's classification. For example, the internal circuitry shall be designed to include isolation features that require two independent failure modes (as a minimum) before the specified output current can be exceeded. New, revised, or functionally modified Type I and II instruments shall undergo a comprehensive failure analysis to meet this design requirement. Type III instruments shall be reviewed by the HEIC before approval for a specific use.
- Where possible, a comprehensive (point-to-point) check should be made to ensure the electrical wiring corresponds to the wiring diagram and that all components function properly and within specifications.

- Type I and II instruments shall be designed such that their available short-circuit current can be verified before each use. These instruments shall be battery-powered, and their test connections shall be verifiably incapacitated during any battery-charging operation.

3.4 Qualification and Approval of Instruments

The procedure for qualifying, certifying, and approving instruments for use with explosives systems is as follows:

1. The intended user submits the following to the HEIC at least two months in advance of the use date:
   - The commercial model or prototype of the instrument
   - A complete set of drawings
   - The electrical specifications
   - Test data
   - Other pertinent information about the instrument
2. The HEIC does the following:
   - Arranges for a failure analysis to be performed if the instrument requires Type I or II qualification.
   - Instructs the Electronics Engineering Department (or its designee) to inspect and test the instrument to meet the requirements described in this document.
   - Reviews and approves the instrument and test data.
3. The Electronics Engineering Department (or its designee) develops a written calibration/certification procedure and a calibration data report for the instrument. The procedure is structured so that work can be reproducible. Automated test procedures are *not* authorized.
4. The HEIC approves the certification/calibration procedure in accordance with the facility procedures for the Electronics Engineering Department.
5. The HEIC chairperson generates a memorandum approving the new instrument as either Type I, II, or III. He/she then notifies the chairperson of the DOE Explosives Safety Committee (ESC) in writing of the approval of instruments for use with initiating systems (see *DOE Explosives Safety Manual*). The HEIC chairperson then informs other DOE contractor organizations of instrument approvals. The LLNL representative of the DOE ESC notifies the HEIC in writing of instruments qualified by other DOE contractor organizations.

3.5 Instrument Verification and Use

To demonstrate continued safe use while in service, the instrument's current output must be checked frequently. All instruments used on initiating circuits shall have their current-limiting features verified before each use. A Fluke 8025A Type III instrument is used to check the SE-3065 Type I instrument (refer to "Fluke 8025A and SE-3065 Checkout Procedure," which can be obtained from the HEIC). Only approved and certified instruments shall be used to verify the output current of instruments used on initiating systems. If any instrument exceeds $\pm$5% of the expected value, that instrument shall be withdrawn from service and returned to the Electronics Engineering Department for repair and recertification.

If the application so requires, Type I instruments may be used in lieu of Type II or Type III, and Type II instruments in lieu of Type III. Under no circumstances shall Type II or Type III instruments be used as Type I, nor shall Type III instruments be used as Type II unless the operation is conducted remotely and is covered by an approved safety plan (FSP or OSP) and authorized by an IWS.

3.6 Instrument Controls

All certified instruments shall be kept under strict administrative control to prevent misuse. In addition, Type III instruments used on noninitiating systems shall meet the following requirements:

- New, revised, or functionally modified Type III instruments must be thoroughly reviewed by the HEIC before being approved. *These instruments shall not be released to the user without an authorized IWS and an approved safety plan.*
- All uses of Type III instruments shall be analyzed to ensure that their normal test energy will not ignite the explosives in the system during the test.
- If the instruments are used to measure sensors directly applied to explosives systems (e.g., bonded strain gauges or pin switches), they shall meet the output current limitations described in Section 3.3.
- Because many Type III instruments do not meet the requirements for initiating systems, all restrictions shall be prominently affixed to the instruments.

The term "restricted use," along with a reference to the document containing the specific restrictions for use (e.g., approved safety plan), shall be prominently displayed on Type III instruments approved for use in a contact mode.

4.0 Responsibilities

All workers and organizations shall refer to Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management" for a list of general responsibilities. This section describes specific responsibilities of LLNL organizations and workers who have key safety roles.

4.1 High Explosives Instrument Committee

The HEIC is appointed by the deputy associate directors for the Electronics Engineering and the Mechanical Engineering departments. The committee is made up of personnel from the Electronics Engineering Department, the Mechanical Engineering Department, and the Hazards Control Department who are knowledgeable in specific areas of electrical instruments used in explosives operations. The HEIC is responsible for

- Reviewing electrical instruments proposed for use on explosives systems.
- Approving electrical instruments that meet specified requirements.
- Establishing a formal system for controlling all instruments used on explosives systems.
- Defining certification procedure requirements for approved electrical instruments.
- Reviewing and approving the individual instrument operating procedures.
- Recommending additions or changes to the instrument control system when appropriate.
- Reviewing this document annually and initiating revisions as needed.

The HEIC chairperson is responsible for ensuring that the appropriate documentation for any HEIC action is completed and that this information is disseminated to appropriate personnel (e.g., facility supervisors, program personnel and ES&H Team explosives safety engineers).

4.2 Electronics Engineering Department

The deputy associate director for the Electronics Engineering Department (or his/her designee) is responsible for appointing members to the HEIC and for ensuring that a formal program exists within the department for the following:

- Cataloging, labeling, color-coding, and certifying electrical instruments in accordance with this document.

- Testing, repairing, and calibrating electrical instruments used on explosives systems in accordance with instrument-specific procedures.
- Maintaining failure analysis and service records for all instruments approved by the HEIC for use on explosives systems. Records shall be maintained for the life of all instruments certified.
- Affixing a tamper-resistant seal (Fig. 4) to instruments to ensure their internal integrity and a Notice of Certification label (Fig. 5) to certify their electrical performance and the calibration date. The calibration expiration date shall be no longer than one year from the date of last calibration and certification. Instruments whose calibration date has expired shall not be used on explosives systems. *Removal or defacement of either the tamper-resistant seal or the Notice of Certification label shall be cause for immediate return of an instrument to the person or group responsible for recertification.*

Figure 4. Tamper-resistant seal.

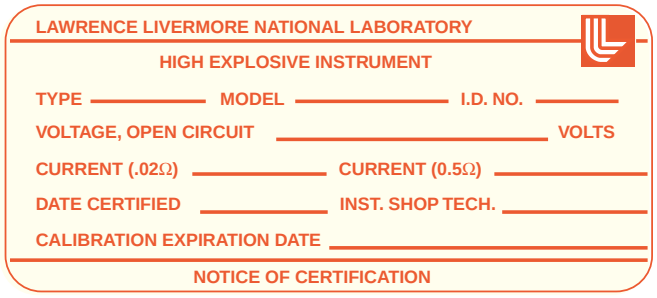

Figure 5. Notice of Certification label.

4.3 Mechanical Engineering Department

The deputy associate director for the Mechanical Engineering Department (or his/her designee) is responsible for appointing members to the HEIC.

4.4 Work Supervisors

Supervisors are responsible for the following:

- Ensuring that personnel operating test instruments with explosives systems are properly trained and qualified to use those instruments. To be qualified, employees must be able to demonstrate to their work supervisors the proper use of each instrument and show an understanding of the differences between explosives systems. All training must be documented in the employee's Training Qualification Record (Form RL-2999-9) or equivalent.
- Evaluating all proposed use of test instruments to ensure that they are appropriate for the application.

4.5 Users

Individuals who use electrical instruments with explosives systems are responsible for the following:

- Evaluating the proposed use of the test instruments and for ensuring that their capability and qualifications are appropriate for the application.
- Ensuring that all Type I, Type II, and Type III electrical instruments are approved, certified, and calibrated, and that all labels and seals are in place.
- Providing an account number to which the costs associated with instrument qualification and approval can be charged.
- Following instrument-specific operating procedures attached to or included with each instrument.
- Using the instrument appropriately. This includes understanding all aspects of the instrument and the consequences of substituting the different types of instruments. Special conditions for use as stated in the safety plan shall be followed.
- Instruments shall not be used on explosives systems if any of the following conditions exist:
  - Calibration expiration date has expired.
  - Tamper-resistant seal has been broken.
  - Notice of Certification label has been removed or defaced.
  - Before-use check indicates a current output that exceeds specifications or ±5% of the expected value.

Instruments meeting any of the above conditions shall be immediately returned to the person or group responsible for calibration and certification.

5.0 Work Smart Standards

DOE M 440.1-1, *DOE Explosives Safety Manual*.

DOE O 452.2B, Safety of Nuclear Explosive Operations, § 4.e.(11)(a), Control of Electrical Testers/Equipment.

6.0 Resources for More Information

6.1 LLNL Contacts

For further information about this document, contact the following as necessary:

- High Explosives Instrument Committee chair or its members
- Hazards Control Safety Programs Division, explosives safety technical leader
- ES&H Teams

6.2 Applicable Lessons Learned

The Lessons Learned Program is available on the Internet at the following URL address:

http://www-r.llnl.gov/es_and_h/lessons/lessons.shtml

6.3 Other Sources

"Electrical Instruments for Use with Explosives Systems," Lawrence Livermore National Laboratory, California, Nuclear Test Operations Procedure No. NTS-402, April 1998.

"Fluke 8025A and SE-3065 Checkout Procedure," Lawrence Livermore National Laboratory, California, Site 300 Procedure No. B/S300 96-050.

Appendix A

Terms and Definitions

Approval	Formal documentation authorizing the use of certified test instruments.
Calibration	The comparison of measuring and test equipment of unknown accuracy to a measurement standard of known accuracy in order to detect, correlate, report, or eliminate by adjustment, any variation in the accuracy of the instrument being compared.
Certification	**For instrument documentation**—Formal documentation certifying that the test instrument has been calibrated by a recognized and approved calibration facility and has been calibrated following a very specific set of calibration requirements. **For instrument integrity**—A precalibration review of the instrument, performed by an HEIC-approved individual, to assure that the instrument has not been tampered with, or modified in any way that would affect the integrity of the instrument.
Contact operation	An operation in which an operator and an explosive item are both present with no operational shield.
High-power device	An electroexplosive device (EED) that requires the discharge of high current through the device bridgewire, foil, or other similar device to initiate the device and produce a shock wave.
Low-energy device	All EEDs except exploding bridgewire (EBW) detonators, exploding foil initiators (EFIs) (also known as slapper detonators), or similar high-power devices. These devices can be initiated by a low current.
Qualification	The process that a test instrument must go through to ensure compliance with specific acceptance requirements.

Remote operation	An operation performed in a manner that will protect personnel in the event of an accidental explosion. This can be accomplished by distance, shielding, barricades, or a combination thereof.

Appendix B

Approved Instruments*

Below is a list of approved electrical test instruments and their specific uses with explosives systems.

Instrument	Type	Specific use
Fluke 8012A/AD (Sandia SE-3065)	I	Ohmmeter used on initiating and noninitiating circuits
Fluke 8025A	III	Testing the Fluke 8012A/AD
LEA 83-1838-01	III	Strain gauge power supply used on noninitiating circuits
Sandia PT-4030	III	Ohmmeter used with noninitiating circuits

* Only individual instruments designed, tested, and certified as outlined in this document are approved for use with explosives systems in a nonremote operation.